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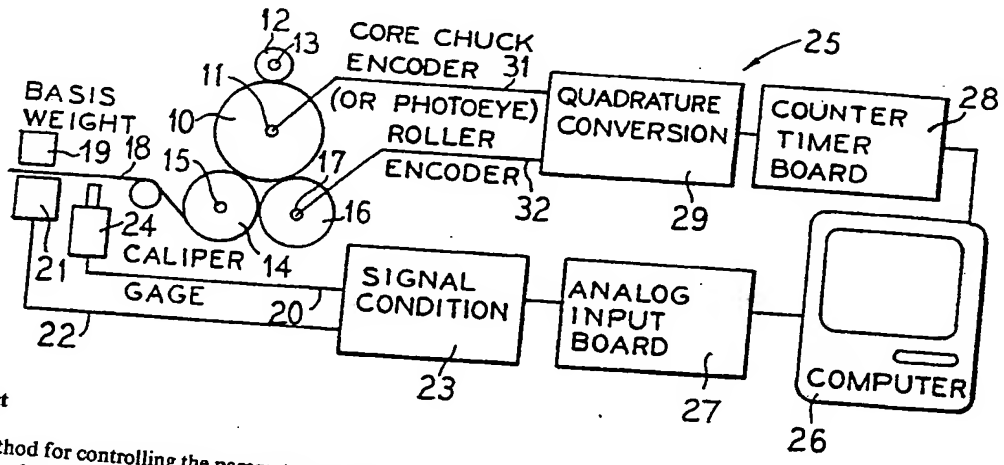

(57) Abstract

A method for controlling the parameters of a web winding machine affecting the roll (10) structure which includes a system that utilizes a density analyzer (25), a basis weight measuring device (19, 21), and a caliper measuring device (24) with customized software and a PID control of the equipment controlling the tension, nip pressure and torque transmitted to the web (18) which is being wound and a computer (26). The basis weight and caliper measuring devices (19, 21, 24) are mounted at a location so as to mesure the web properties immediately before it is wound into roll form. The density analyzer (25) is connected to the machine in its usual form. The basis weight and caliper measuring device (19, 21, 24) determines the "free sheet" density while the density analyzer (25) determines the "wound roll density". The difference between these two values can be used to control the parameters affecting the roll (10) structure.

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CLOSED LOOP CONTROL FOR A WEB WINDING MACHINE

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates in general to a web winding machine for paper and other products and particularly to a closed loop control for a web winding machine.

Description of the Related Art

U. S. Patent No. 4,594,880 discloses an apparatus for determining the finished roll density in a mill and such disclosure is hereby incorporated by reference.

U. S. Patent No. 3,009,666 relates to roll density control for slitter winders and such disclosure is hereby incorporated by reference herein.

U. S. Patent 4,883,233 is to a method for controlling the reeling of a web and this disclosure is hereby incorporated by reference into the present disclosure.

U. S. Patent 4,638,657 is to a device for measuring the winding hardness of a strip especially a strip of paper wound into a reel.

U. S. Patent 4,676,094 is to a roll-firmness measuring device and this disclosure is hereby incorporated by reference into the present disclosure.

Measuring a wound roll density on line is perhaps the most useful diagnostic tool that exists for measuring roll structure. Various density

analyzers have been in existence since 1980. In 1983, the Voith Company had the ability to correct for machine direction caliper variations in the density calculation. This method offers significant advantages over non-caliper corrected analyzers. The basic calculation for wound roll density is as follows:

$$\text{Density} = \frac{\text{Basis Weight}}{\text{Ream Size} * 144 * \text{Caliper}}$$

Density = [#/in 3
Basis weight = [#/Ream Size]
Ream size = [ft 2]
Caliper = [inches]

As can be seen from this equation, the calculation of wound roll density is highly dependent upon the basis weight and the caliper of the material being wound.

There have been attempts to provide closed loop control of the parameters effecting roll structure previously. Most of these have relied upon controlling these parameters based upon either "feed forward" techniques or by controlling them via ~wound roll" density equaling preset values that were determined by a human "expert". Both of these techniques have significant errors associated with them. The "feed forward" technique assumes that the web properties are following a trend and that these trends can be predicted. Although this may be correct a small percentage of the time, it is not accurate enough to use according to statistical methods for prediction. A human "expert" technique assumes that the web properties are constant. This assumption is invalid. Web caliper and basis weight may vary independently by as much as 10% in a roll of material. This can lead to changes in the resultant "density" curve of as much as 1015%. When attempting to determine the fitness of a roll structure, this is not adequate.

It is desirable to produce rolls of material with a known roll structure. With manual operation, there is a high amount of variation in the resulting roll structure from operator control of the parameters effecting roll structure. Every operator tends to set the parameter slightly different from others based upon his/her experience with the machine and the resultant roll structure. There have been attempts previously to have automated "control" of the parameters effecting roll structure. For the most part, they have been based upon one of two methods.

The first method is the most widely implemented. It involves a human "expert" who determines what the optimum setting is for the parameters should be for "ideal" roll structure. There are typically different curves for different grades and roll diameters. The major problem with this method is that it is based upon the assumption that the paper properties and machine characteristics are constant. This is not a valid assumption. Web caliper and basis weight may vary independently by as much as 10% within a roll of material. Hence, the preset curves may produce different roll structures for different rolls of the same grade and diameter.

The second method involves a technique known as "feed forwarding". This method involves measuring either the roll structure or wound roll density during a particularly run. The computer then modifies the parameters affecting roll structure according to a set rules or tables in order to produce the desired roll structure. The next roll is then wound with each of the parameters. This process is repeated roll after roll. The major problem with this method is that it assumes that there is a statistical trending to the web properties and the way it reacts to the various parameters affecting roll structure. The primary diagnostic tool is wound roll density. This measurement is highly influenced by variations and web

caliper and basis weight. Neither of these variables can be statistically trended with any reasonable amount of confidence.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved roll density monitoring system. This includes on line measurement of web caliper and basis weight. By measuring the "free sheet" density and comparing that with the "wound roll" density, a determination of the effectiveness of the parameters controlling the machine can be made. Although "wound roll" density is not a primary roll structure measurement, it can be used in the method of the invention to control the winding parameters "real-time" so as to obtain a desired roll structure.

There are several different methods by which this could be done. They include the following:

1. Calculating the difference between the "free sheet" density and the "wound roll" density.

2. Integrating the area between the two densities. This could be used to indicate the amount of energy "stored" in the roll.

In either method, one could do the following:

1. Look at the absolute numbers and use that to control the machine.

2. Look at the relative changes between successive points. With the differencing method, this would indicate that there is an "area" of

"high" density next to a "area" of "low" density. With the integrating method, this would indicate that there is a "area" of "high" energy next to an "area" of "low" energy. The magnitude of these changes could be used to diagnose whether or not there is a problem with the roll structure. A computer with current density information would be able to influence the winding parameters based on the density data. This computer would contain an expert system and/or PID control winding parameters.

It is an object of the present invention to use conventional prior art wound roll density analyzing equipment with the addition of the measurement of web caliper and basis weight.

Other objects, features and advantages of the invention will be readily apparent from the following description of certain preferred embodiments thereof taken in conjunction with the accompanying drawings although variations and modifications may be effected without departing from the spirit and scope of the novel concepts of the disclosure, and in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates the invention;

FIG. 2 is an end view of a reel showing its diameter at two different locations;

FIGS. 3-11 are curves illustrating various characteristics of rolls.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates the paper roll 10 being wound on a spindle 11 and the wound roll 10 is engaged at its top surface by a roll 12 mounted on a shaft 13. A first drum 14 is rotatably supported on a shaft 15 and engages the lower surface of the roll 10. A second drum 16 mounted on a shaft 17 engages the lower surface of the finished paper roll 10 as shown. The incoming paper web 18 passes through a basis weight measuring device comprising elements 19 and 21 mounted on opposite sides of the web 18 which supplies an output signal indicative of basis weight on lead 22 to a signal condition unit 23. A caliper gauge 24 is mounted adjacent the web 18 and measures the caliper and supplies an output on lead 20 to the signal condition unit 23. The signal condition unit 23 supplies an output to an analog input board 27 which supplies an input to a computer 26. The computer 26 receives the output of a wound roll density analyzer 25 which comprises a counter timer board 28 which supplies an output to the computer 26 and which receives an input from a quadrature conversion unit 29 which receives inputs on leads 31 from a core chuck encoder which measures the speed of the paper roll 10 by detecting the rotational speed of the shaft 11. The quadrature conversion 29 also receives an input on lead 32 which indicates the speed of rotation of the shaft 17 which supports the drum 16.

The wound roll density analyzer 25 is known in the prior art and the present invention adds the basis weight measuring device and the web caliper device.

It is desirable to control the parameters affecting the roll structure "real-time" during winding. With all prior art equipments, this is impossible. At best, current methods modify the machine parameters based upon what

the perceived effect was on the previous roll structure. This is not "real-time" and it is based on the assumption that the web properties and their affect on roll structure can be statistically trended. With the system of the invention, it is possible to obtain "real-time" control of the winding parameters so as to achieve a desired roll structure.

There are several different methods to accomplish this. They include the following:

1. Calculate the difference between the "free sheet" density and the "wound roll" density.

2. Integrate the areas between the two densities. This could be used to indicate the amount of energy stored in the roll.

FIGS. 3-6 illustrate the curves for the different methods of analysis listed above based upon typical "round roll" and "free sheet" densities. FIGS. 710 illustrate the curves for all of the different methods of analysis listed above based upon variations in the "round roll" density while there is none in the "free sheet" density. FIGS. 10 and 11 show the curves for the methods based upon similar variations and "wound roll" and the "free sheet" densities.

In either method, the following can be done:

1. Consider the absolute numbers and use those to control the machine.

2. Consider the relative change between successive points. With the differencing method, this would indicate that there is an "area" of

"high" density next to an "area" to "low" density. With the integrating method this would indicate that there is an "area" of "high" energy next to an "area" of "low" energy. The magnitude of these changes could then be used to diagnose whether or not there is a problem with the roll structure.

With either system, it would be desirable to have an expert system controlling the machine. This system would be programmed with the required rules and their associated confidence level for a desired roll structure. This system may also possess the ability to accept information from post-processing tests that indicate the roll structure as measured from a primary unit of measurement. Such tests include the WIT-WOT winder from Beloit Corporation or a TAPPI standard Cameron gap test. With the acceptance of this data, the expert system could then update its rules and associated confidence levels for the producer's materials.

FIG. 2 is an end view of a roll of paper and indicates an annular paper portion Fi between diameters Di (outer) and Di1 (inner).

FIG. 3 is a plot of the roll diameter in inches of the wound roll density and the free-sheet density.

FIG. 4 is a plot of the roll diameter wound minus free sheet.

FIG. 5 is a plot of roll diameter in inches of the integrated single point.

FIG. 6 is a plot of roll diameter in inches integrated 0 to 60 inches.

FIG. 7 is a plot of roll diameter in inches wound roll density and free sheet density.

FIG. 8 is a plot roll diameter in inches with the wound minus the free sheet plotted.

FIG. 9 is a plot of roll diameter in inches with the integrated single point.

FIG. 10 is a plot of the roll diameter with wound roll density and the free sheet density.

FIG. 11 is a plot of the roll diameter and the integrated single point.

Thus, the present invention utilizes the basis weight and caliper gauge with the wound roll density so as to accurately control the rolls.

It is seen that this invention provides an improved structure for controlling roll structures and although the invention has been described with respect to preferred embodiments, it is not to be so limited as changes and modifications can be made which are within the full intended scope of the invention as defined by the appended claims.

WE CLAIM AS OUR INVENTION:

1. A method for controlling the roll structure of a web (18) wound on a winding machine consisting of the steps of, determining the density of the wound web (10), measuring the basis weight of the web (19,21) before it has been wound, measuring the caliper of the web (24), and calculating (23,24,26) the parameters of said winding machine.

2. A method according to claim 1 wherein the parameters are calculated from the difference between the "free sheet" density and the "wound roll" density.

3. A method according to claim 1 wherein the parameters are calculated by integrating the area between the "free sheet" density and the "wound roll" density.

4. Apparatus for controlling the roll (10) structure of a web (18) wound on a winding machine comprising, a web (18) which is to be wound, a basis weight detector (19,21) mounted adjacent the web to detect the basis weight, a caliper gage (24) mounted adjacent the web to detect the caliper, means (28,29,31,32) for determining the density of the wound web on the winding machine, and a computer (26) receiving the outputs (22,20,25) of said basis weight detector, said caliper gage and said means for determining density of the wound web and calculating the parameters of said winding machine.

5. Apparatus for controlling the roll structure of a web wound on a winding machine according to claim 4 including a signal condition means (23) and an analog input board (27) mounted between said computer (26) and said caliper gage (24) and said basis weight detector (19,21).

FIG. 1

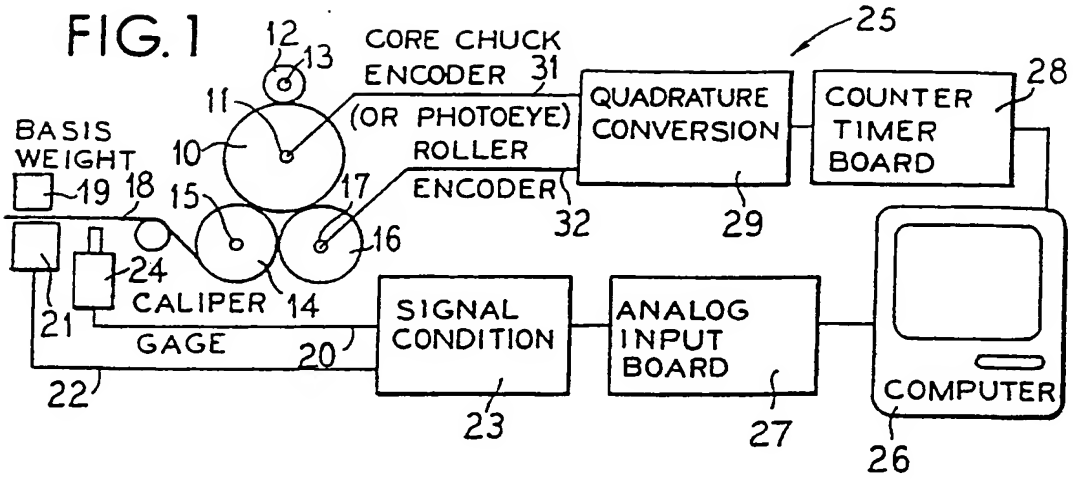

12
13
CORE CHUCK
ENCODER 31
11
(OR PHOTOEYE)
ROLLER
ENCODER
32
25
QUADRATURE
CONVERSION
29
COUNTER
TIMER
BOARD
28
BASIS
WEIGHT
19
10
18
15
17
16
24
CALIPER
14
21
GAGE
20
22
SIGNAL
CONDITION
23
ANALOG
INPUT
BOARD
27
COMPUTER
26

FIG. 2

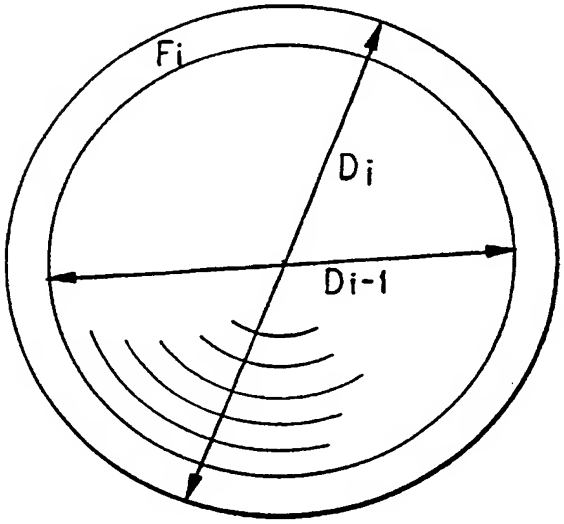

Fi
Di
Di-1

FIG. 3

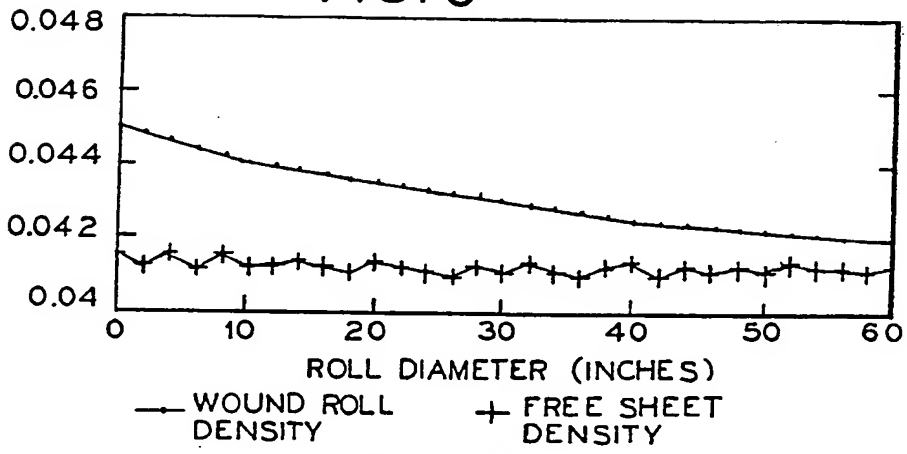


FIG. 4

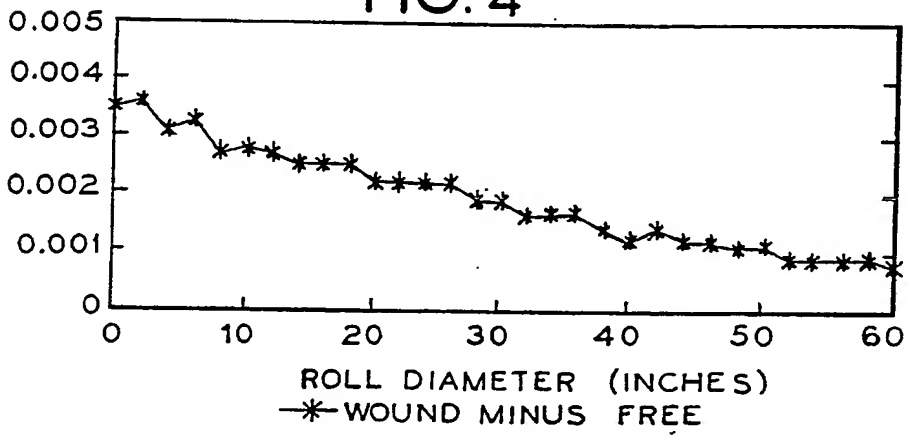


FIG. 5

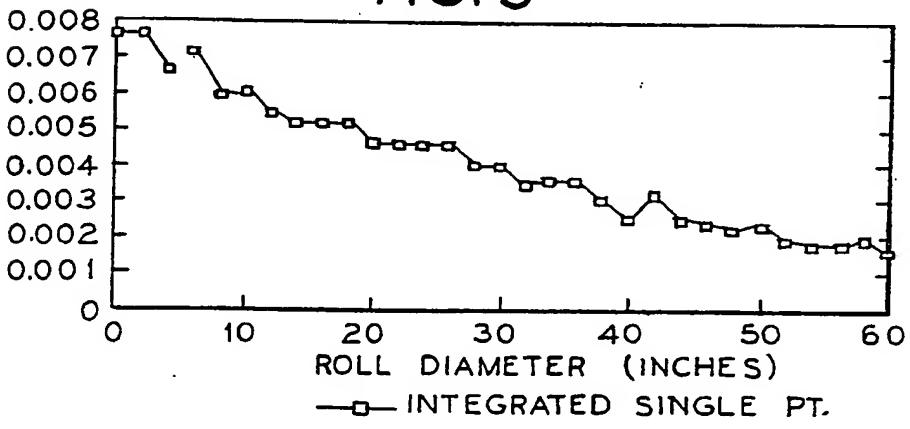


FIG. 6

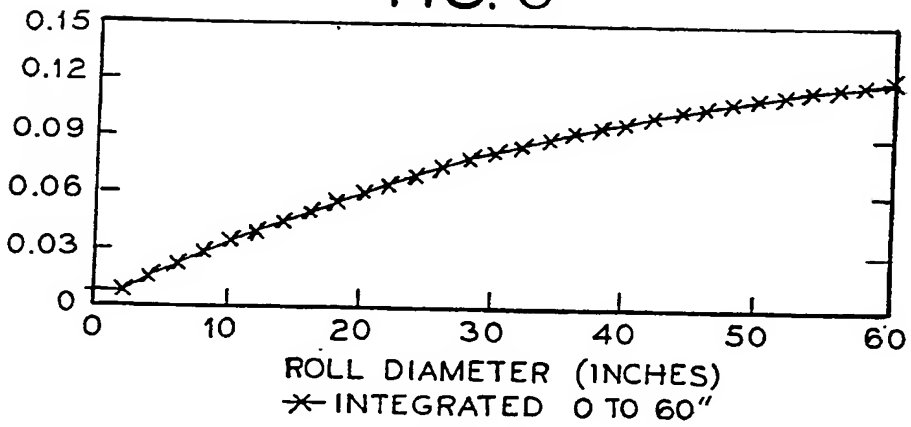


FIG. 7

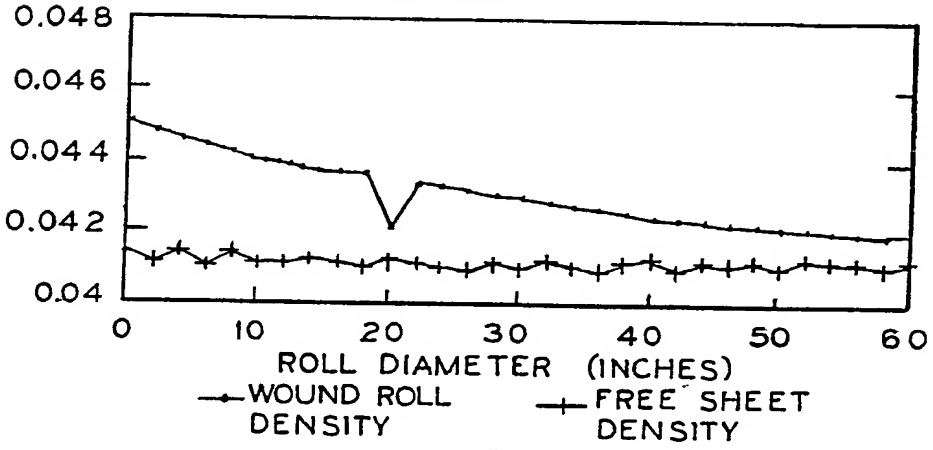


FIG. 8

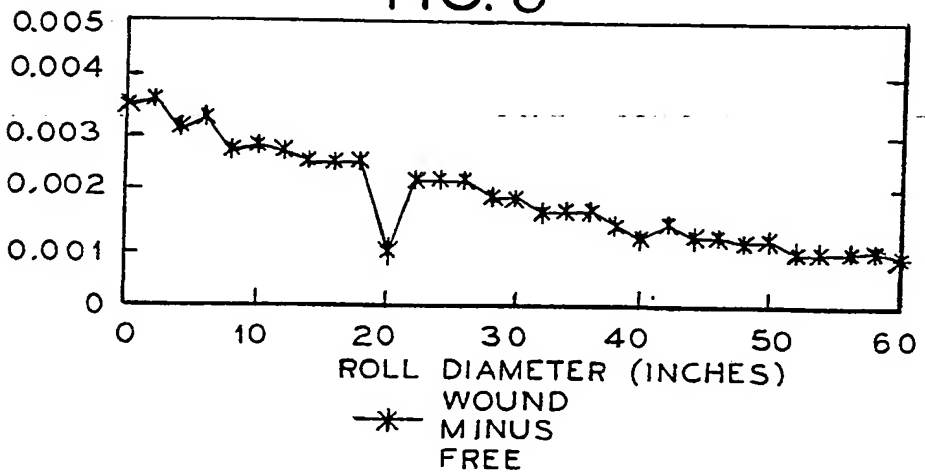


FIG. 9

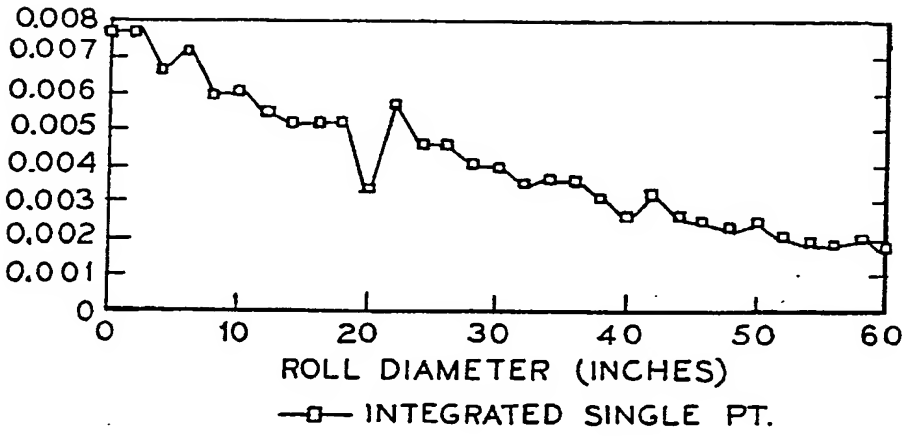


FIG. 10

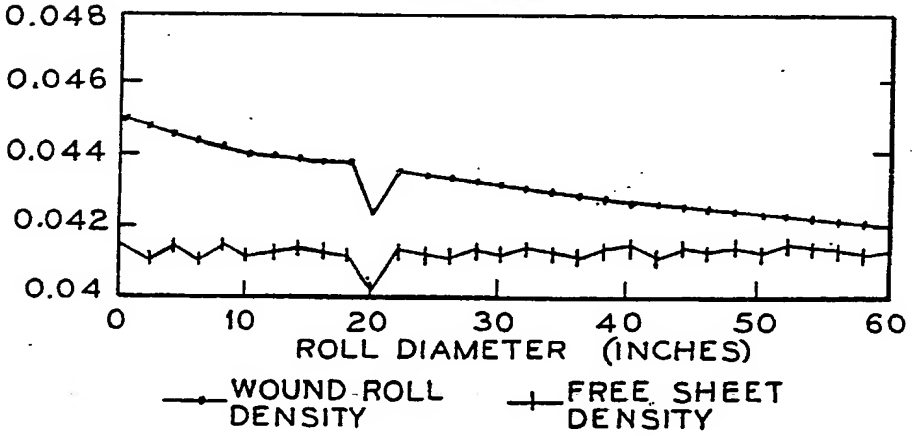
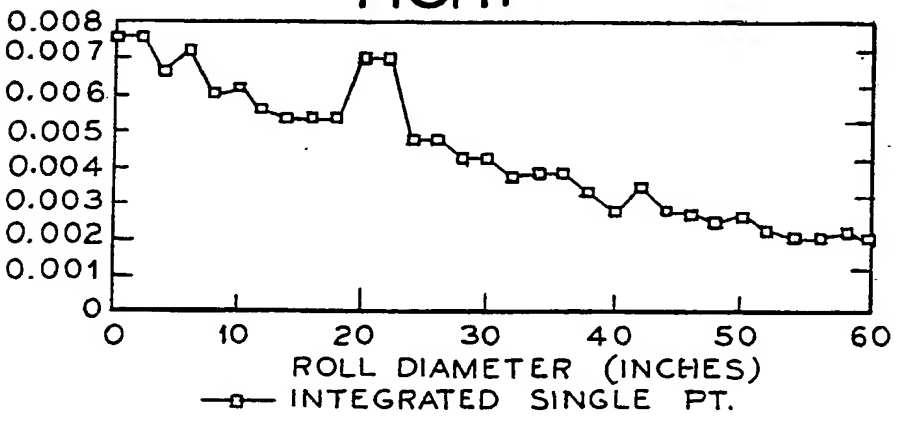


FIG. 11



INTERNATIONAL SEARCH REPORT

International Application No PCT/US 93/00695

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 B65H18/26; B65H23/195; G01N33/34; G01N9/00

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	B65H ; G01N

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
P,X	WO,A,9 220 601 (BRÜCKNER MASCHINENBAU GERNOT BRÜCKNER GMBH & CO. KG) 26 November 1992 see the whole document ---	1,4,5
Y	GB,A,2 117 935 (ASEA AKTIEBOLAG) 19 October 1983 see claim 4; figure 2 see page 2, line 62 - line 102 ---	1,2,4,5
Y	EP,A,0 233 389 (J.W. REPSCH ET AL.) 26 August 1987 see claims 1,6 see column 1, line 1 - line 10 see column 2, line 16 - line 28 see column 4, line 40 - column 5, line 15 ---	1,2,4,5

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
13 MAY 1993	17. 06. 93
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	HAEUSLER F.U.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	DE,A,2 439 212 (FELDMÜHLE ANLAGEN- UND PRODUKTIONSGESELLSCHAFT MBH) 26 February 1976 see claims 1-3; figures 1-5 see page 4, line 20 - page 5, line 8 see page 6, line 1 - page 7, line 12	1,2,4
A	US,A,4 883 233 (S. SAUKKONEN ET AL.) 28 November 1989 cited in the application see claims 1,2,9,10 see column 2, line 64 - line 69	1,4
A	EP,A,0 397 594 (BELOIT CORPORATION) 14 November 1990 see claims 5,6	1,4
A	GB,A,710 124 (THE BRITISH THOMSON-HOUSTON COMPANY, LIMITED) 9 June 1954 see page 1, line 10 - line 19 see page 3, line 23 - line 32	1,4
A	US,A,3 909 615 (J. BOSCH) 30 September 1975 see abstract	1,4
A	US,A,4 535 950 (K. LISNYANSKY) 20 August 1985 see claims 1,4-6 see column 3, line 25 - column 4, line 41	1,4
A	TAPPI JOURNAL vol. 66, no. 1, 24 January 1983, ATLANTA US pages 63 - 66 L.G. ERIKSSON ET AL. 'Measurement of paper roll density during winding' see the whole document	1

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

US 9300695
SA 69854

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO-A-9220601	26-11-92	DE-A-	4116081	19-11-92
GB-A-2117935	19-10-83	SE-B-	450703	20-07-87
		CA-A-	1191930	13-08-85
		DE-A-	3310296	06-10-83
		FR-A,B	2524448	07-10-83
		JP-A-	58183554	26-10-83
		SE-A-	8202095	02-10-83
		US-A-	4496112	29-01-85
EP-A-0233389	26-08-87	CA-A-	1202431	25-03-86
DE-A-2439212	26-02-76	None		
US-A-4883233	28-11-89	DE-A-	3816777	08-12-88
EP-A-0397594	14-11-90	US-A-	5023820	11-06-91
		JP-A-	2310244	26-12-90
GB-A-710124		None		
US-A-3909615	30-09-75	DE-A-	2306550	15-08-74
		FR-A,B	2217690	06-09-74
		GB-A-	1429156	24-03-76
US-A-4535950	20-08-85	CA-A-	1229151	10-11-87

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